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RESEARCH MEMORANDUM

DRAG MEASUREMENTS IN FLIGHT ON THE 10-PERCENT-THICK AND 8-PERCENT-THICK WING X-1 AIRPLANES

By

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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DRAG MEASUREMENTS IN FLIGHT ON THE 10-PERCENT-THICK AND 8-PERCENT-THICK WING X-1 AIRPLANES

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SUMMARY

Drag measurements have been made on the 10-percent-thick wing, 8-percent-thick tail and the 8-percent-thick wing, 6-percent-thick tail X-1 airplanes in a joint Air Force-NACA flight-test program at Muroc Air Force Base, California. The Mach number range covered in these tests was from approximately 0.7 to 1.3.

The results indicate that the drag of the 10-percent-thick wing airplane was considerably greater than that of the 8-percent-thick wing airplane, as much as 80 percent at Mach number = 1.0. Interference shown to be present between fuselage and wing makes the separation of wing drag and fuselage-tail drag difficult.

Values of airplane lift-drag ratio for the two airplanes were quite low at Mach number = 1.0, being 1.5 and 2.8 for the 10-percent-thick wing and 8-percent-thick wing airplanes, respectively. A maximum lift-drag ratio for the 8-percent-thick wing airplane of from 3.0 to 3.5 was indicated for the optimum lift coefficient condition at Mach number $\approx$ 1.16.

INTRODUCTION

In the course of loads and stability and control flight tests on the X-1 airplanes at Muroc Air Force Base, California, drag measurements were made on both the 10-percent-thick wing and 8-percent-thick wing X-1 airplanes. These tests were a part of a joint Air Force-NACA transonic-supersonic flight-test program. Since primary interest in the X-1 flight-test program was concentrated on stability and control and loads measurements, it was not possible to install instrumentation especially suited for drag measurements; but, instead, it was necessary to use instruments already in the airplane for these other tests.

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This report gives the results of over-all drag measurements of the two X-1 airplanes in the Mach number range of approximately 0.7 to 1.3. These results are limited inasmuch as data were available from only a few flights.

SYMBOLS

M	airplane Mach number
q	stream dynamic pressure, pounds per square foot
C_N	airplane normal-force coefficient $\left(\dfrac{n_v W}{qS}\right)$
C_{D_t}	airplane total drag coefficient, based on wing area
c_n	section normal-force coefficient
L/D	airplane lift-drag ratio
l/d	section lift-drag ratio
c_c	section chordwise force coefficient
c_l	section lift coefficient
c_d	section drag coefficient
T	thrust of rocket motor, pounds
D	drag of airplane, pounds
W	weight of airplane, pounds
S	airplane wing area, square feet
n	acceleration, g units
n_h	acceleration along airplane longitudinal axis
n_v	acceleration normal to airplane longitudinal axis
$n_{f.p.}$	acceleration along flight path
α	angle between airplane longitudinal axis and the flight path, degrees

α_0 value of α at $C_N = 0$

P_c rocket chamber pressure, pounds per square inch absolute

A_t rocket nozzle throat area, square inches

C_f thrust coefficient of rocket system

A_e rocket nozzle exit area, square inches

P_e rocket nozzle design discharge pressure, pounds per square inch absolute

P_a ambient pressure, pounds per square inch absolute

AIRPLANE

The general physical characteristics of the Bell X-1 type airplane are reported in reference 1. The 10-percent-thick wing and 8-percent-thick wing airplanes differ only in wing and tail thickness. Both airplanes are powered by a four-cylinder liquid-fuel rocket-type engine having a 6000-pound static sea-level thrust rating. Throttling is obtained only in increments of 25 percent, 50 percent, 75 percent, and 100 percent of full rating.

In figure 1 is shown a three-view drawing of the X-1 type airplane. On this drawing is indicated the location of the midsemispan pressure-distribution survey on the 8-percent-thick wing airplane. In figure 2 is shown a photograph of the 8-percent-thick wing airplane under single-cylinder powered flight.

METHODS

The over-all drag data presented herein have been evaluated by the accelerometer method (reference 2) where

$$D = T - Wn_{f.p.}$$

and

$$n_{f.p.} = n_h \cos \alpha - n_v \sin \alpha$$

(see figure 3) and

$$\alpha = \frac{C_N}{dC_N/d\alpha} + \alpha_o$$

The thrust of the rocket motor was derived from the relation

$$T = P_c A_t C_f + A_e \left(P_e - P_a\right)$$

The values of P_c and P_a were recorded, the other quantities were obtained from test data supplied by the manufacturer. The weight of the airplane was obtained from a time history of propellant and nitrogen consumption and the gross weight at the time of drop of the X-1 from the B-29.

A standard NACA three-component recording accelerometer was mounted near the center of gravity of the airplane with the three axes of the instrument respectively parallel with the three axes of the airplane. From these records, values of n, n_h, and n_v were obtained.

An average value of $dC_N/d\alpha$ of 0.11, based on values obtained from transonic wing flow and tunnel tests of the X-1 airplane (references 3 and 4), was used to determine α.

ACCURACY OF RESULTS

Errors that may be present in quantities recorded and computed are believed to be within the following limits:

T	±5 percent
W	±2 percent
$n_{f.p.}$	±0.03g
C_N	±3 percent
M	±0.02
C_{D_t}	
At $M \approx 0.8$, at altitudes 20,000 feet	±30 percent
At $M \approx 1.1$, at altitudes 45,000 feet	±10 percent

It should be pointed out that, since the accuracy of determining drag coefficient depends in part on the measurement of the acceleration along the flight path $n_{f.p.}$ a greater degree of accuracy would be expected for flights made at low altitudes where higher values of q and therefore higher ratios of airplane drag to airplane weight would prevail.

RESULTS AND DISCUSSION

<u>Drag of 8-percent-thick wing and 6-percent-thick tail airplane.</u>- The variation of C_{D_t} with M for the 8-percent-thick wing and 6-percent-thick tail configuration is shown in figure 4 for two flights. In both of these flights, climbs were started at approximately 25,000 feet with three rockets on shortly after drop from the B-29. The climbs were continued to an altitude of approximately 45,000 feet. The climbs were not steady and this fact may account for some of the scatter of the data points. The C_N in these tests varied from an average value of 0.4 at low speed to 0.2 at high speed. Sufficient data were not available to present drag curves for constant C_N conditions. The drag variation for the two flights up to a Mach number of 1.1 is similar. At higher Mach numbers, sufficient data were not available from flight 15 to compare the two sets of data. Fairing of the points available has been made but, due to the scatter of the data, no significance should be placed on the differences in the faired curves. It should be noted that the group of points for flight 15 at $M = 1.18$ was obtained in a 20-second level stabilized run after climbing, whereas the points in the Mach number range of $M = 1.1$ to $M = 1.32$ for flight 16 were obtained in a shallow dive while the airplane was accelerating. It is possible that the difference between these two flight conditions accounts for a part of this disagreement. In both flight 15 and flight 16, power-off data points were obtained. These are indicated in figure 4 by flagged points. The power-off points were obtained while the airplane was decelerating after rocket power was turned off. The scatter of the power-off points about the faired curves was random and typical of the rest of the data. It may be seen that no significant difference exists between the power-on and power-off conditions.

<u>Drag of 10-percent-thick wing and 8-percent-thick tail airplane.</u>- In figure 5 is shown the variation of C_{D_t} with M for the 10-percent-thick wing and 8-percent-thick tail airplane. The points with the solid-line fairing represent the results of a single flight, flight 14. This flight was made somewhat similar to the thin-wing test. A climb was begun

at an altitude of approximately 25,000 feet on four rockets shortly after the X-1 was dropped from the B-29. This climb was continued to 45,000 feet altitude. A level stabilized run was then made for 20 seconds, represented by the group of data points at $M = 1.1$. Again as on the thin-wing tests, the climb was not steady and this unsteadiness may account for part of the scatter of the data points. The C_N in this flight varied from an average low-speed value of 0.4 to a high-speed value of 0.2. Sufficient data were not obtained on this airplane to show the effect of C_N on the over-all drag coefficient C_{D_t}. Also shown in figure 5 is a comparison of the flight results with wind-tunnel tests (reference 4) and drop-model tests (reference 5) of the X-1 airplane with 10-percent-thick wing and 8-percent-thick tail configuration. The drop-model and tunnel results were interpolated to obtain C_{D_t} at values of C_N corresponding to those obtained in flight tests.

Comparison of drag results.- In figure 6 is shown a comparison of the drag of the 10-percent-thick wing and 8-percent-thick wing airplanes as a function of Mach number. The drag of the 10-percent-thick wing airplane is 80 percent greater at $M = 1.0$ and 60 percent greater at $M = 1.1$ than the drag of the 8-percent-thick wing airplane. Inasmuch as the drag of the 8-percent-thick wing alone is believed to be less than two-thirds the total drag of the 8-percent-thick wing airplane, the drag increase due to the thicker wing is about twice that to be expected if the wing drag is assumed to vary as the square of the thickness ratio (an assumption generally useful to obtain a first approximation of the effect of thickness on wing drag, see reference 6).

Interference of fuselage with wing.- It might be expected that the blunt fuselage of the X-1 airplane would cause considerable interference with the wing, making the separation of wing and fuselage drag difficult. In figure 7 is shown the variation of the section chordwise force coefficient c_c with Mach number. These data were obtained from an evaluation of pressure-distribution measurements made in flight at the midsemispan station on the 8-percent-thick wing airplane. These pressure-distribution tests have been reported in reference 7. In the Mach number range of $M = 0.92$ to 1.30, in figure 7, the chordwise force is very nearly the section pressure drag at zero lift. Then it is seen that the peak section drag occurs at a Mach number of 0.92. In tests made at the Langley Laboratory of free-fall models with similar wings attached to cylindrical bodies having low interference with the wing, the wing zero-lift drag reached a maximum at a Mach number of about 0.97 (reference 8). It is then evident that at the midsemispan station of these tests, the fuselage has increased the local stream Mach number by 0.05. It can be expected that at the wing root the effect will be more than the 0.05 effect at the midsemispan station. From these results, it can be concluded that the fuselage is affecting the velocity field of the wing and it would be difficult to divide the over-all airplane drag into wing drag and fuselage-tail drag.

Airplane and section lift-drag ratios.- The drag curves of figure 6 indicate that at $M = 1.0$, the respective values of C_{D_t} for the 10-percent-thick wing and 8-percent-thick wing airplanes were approximately 0.13 and 0.072. At this Mach number the C_N values of both tests were near 0.2. The approximate L/D values $\left(C_N/C_{D_t}\right)$ would then be about 1.5 for the 10-percent-thick wing and 2.8 for the 8-percent-thick wing airplanes.

In figure 8 is shown the variation of the ratio c_n/c_d, approximately the wing section lift-drag ratio, with the section normal-force coefficient c_n for $M \approx 1.16$. These data were worked up from the midsemispan pressure-distribution survey on the 8-percent-thick wing. A skin-friction drag coefficient of 0.006 was added to the section pressure drag coefficient to get c_d. It may be noted that a maximum section lift-drag ratio of approximately 4.5 is reached at a section normal-force coefficient of 0.4 and is maintained over a c_n range of 0.4 to 1.0.

At $c_n = 0.2$, the wing l/d is 3.0, whereas the airplane L/D at this Mach number and lift coefficient was from 2.0 to 2.3. From these data it is evident that at the high altitudes and highest Mach number of these drag tests the airplane was operating at a C_L below that for maximum L/D. If the wing is operated in the region of c_n giving a l/d of 4.5, the L/D of the 8-percent-thick wing airplane might be expected to rise to between 3.0 and 3.5.

CONCLUSIONS

1. The drag of the 10-percent-thick wing airplane was approximately 80 percent greater than the drag of the 8-percent-thick wing airplane at Mach number 1.0, and 60 percent greater at Mach number 1.1.

2. Appreciable interference effects are present between fuselage and wings, making the separation of wing drag and fuselage-tail drag difficult.

3. No significant effects of power on drag were noted in these tests.

4. For the 8-percent-thick wing airplane the section lift-drag ratio l/d for the midsemispan wing section at $M \approx 1.16$ and high altitude was about 3.0, whereas the over-all airplane lift-drag ratio L/D was between 2.0 and 2.3. A maximum wing l/d of 4.5 could be expected at a higher section lift coefficient with corresponding increase in airplane L/D to between 3.0 and 3.5.

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REFERENCES

1. Drake, Hubert M., McLaughlin, Milton D., and Goodman, Harold R.: Results Obtained during Accelerated Transonic Tests of the Bell XS-1 Airplane in Flights to a Mach Number of 0.92. NACA RM No. L8A05a, 1948.

2. Pearson, Henry A., and Beadle, Dorothy E.: Flight Measurements by Various Methods of the Drag Characteristics of the XP-51 Airplane. NACA MR No. L6F12, 1946.

3. Zalovcik, John A., and Sawyer, Richard H.: Longitudinal Stability and Control Characteristics of a Semispan Airplane Model at Transonic Speeds from Tests by the NACA Wing-Flow Method. NACA ACR No. L6E15, 1946.

4. Mattson, Axel T., and Loving, Donald L.: Force, Static Longitudinal Stability, and Control Characteristics of a $\frac{1}{16}$-Scale Model of the Bell XS-1 Transonic Research Airplane at High Mach Numbers. NACA RM No. L8A12, 1948.

5. Matthews, James T., Jr., and Mathews, Charles W.: Determination by the Free-Fall Method of the Longitudinal Stability and Control Characteristics of a $\frac{1}{4}$-Scale Model of the Bell XS-1 Airplane at Transonic Speeds. NACA RM No. L8G29a, 1948.

6. Wetmore, J. W.: A Review of Recent Information Relating to the Drag Rise of Airplanes. NACA RM No. L8A28d, 1948.

7. Beeler, De E., McLaughlin, Milton D., and Clift, Dorothy C.: Measurements of the Chordwise Pressure Distribution over the Wing of the XS-1 Research Airplane in Flight. NACA RM No. L8G21, 1948.

8. Thompson, Jim Rogers, and Marschner, Bernard W.: Comparative Drag Measurements at Transonic Speeds of an NACA 65-006 Airfoil and a Symmetrical Circular-Arc Airfoil. NACA RM No. L6J30, 1947.

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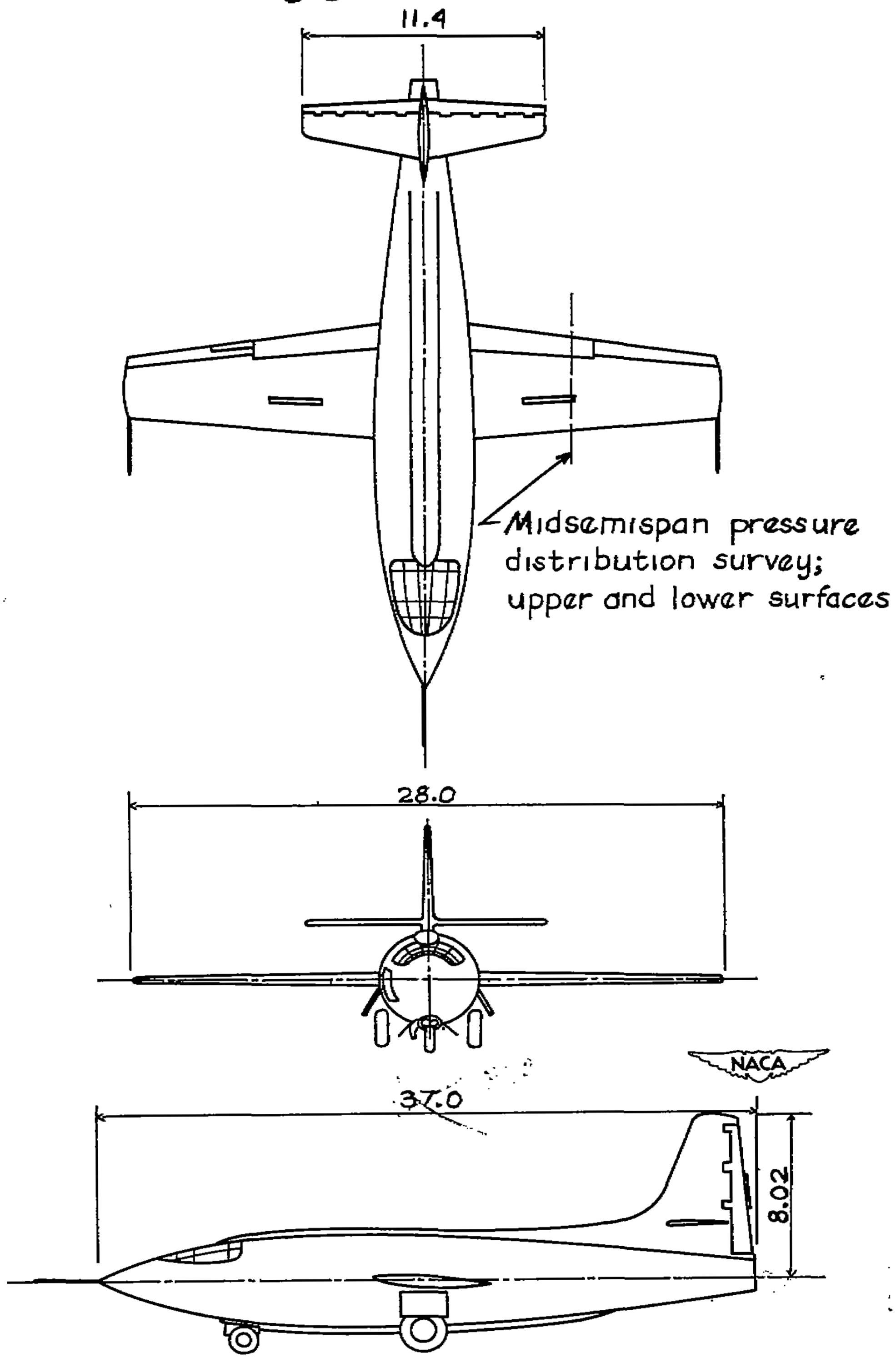

Figure 1.- Three-view drawing of X-1 airplane.

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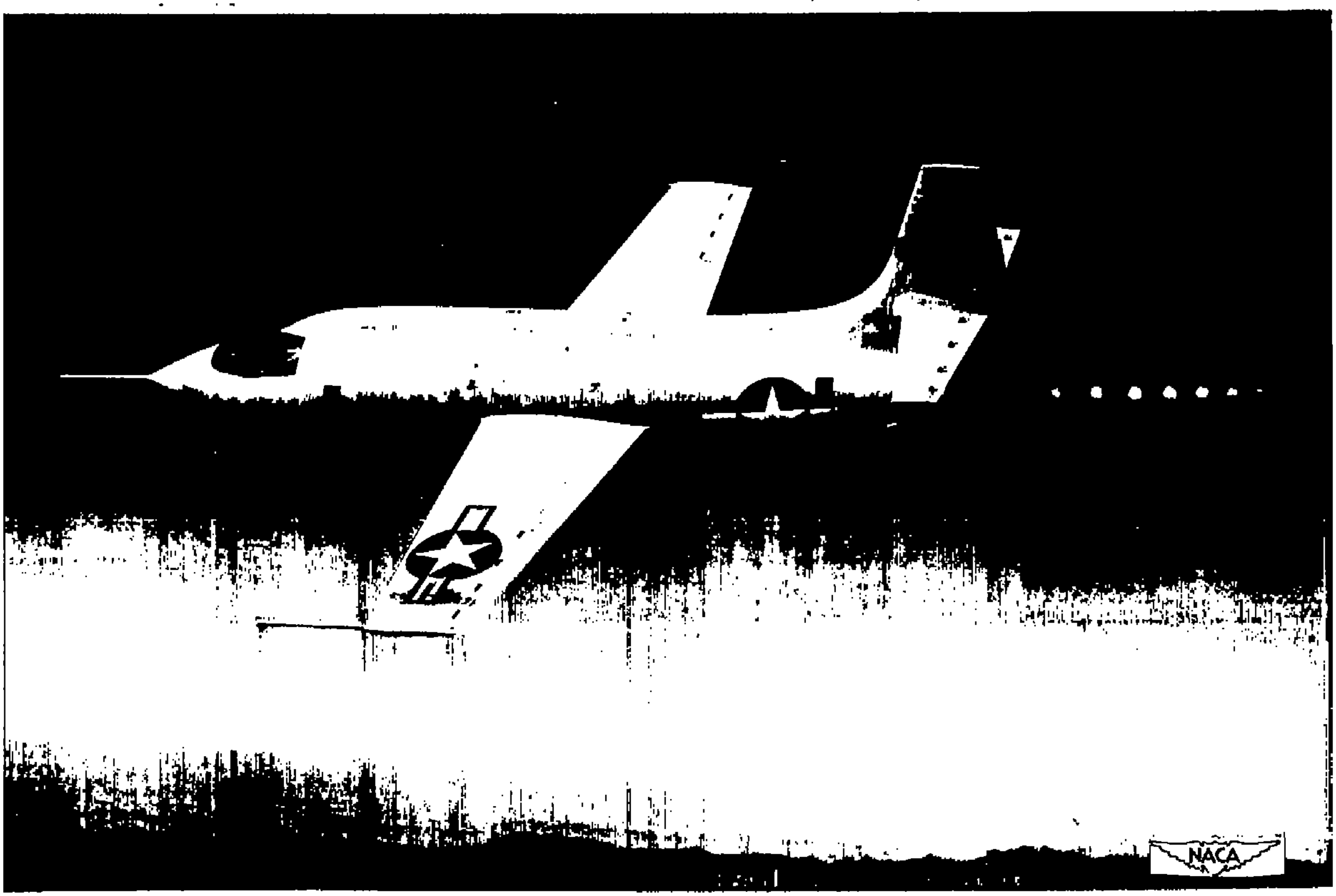

Figure 2.- X-1 airplane in powered flight.

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$$D = T - W n_{f.p.}$$

$$n_{f.p.} = n_h \cos\alpha - n_v \sin\alpha$$

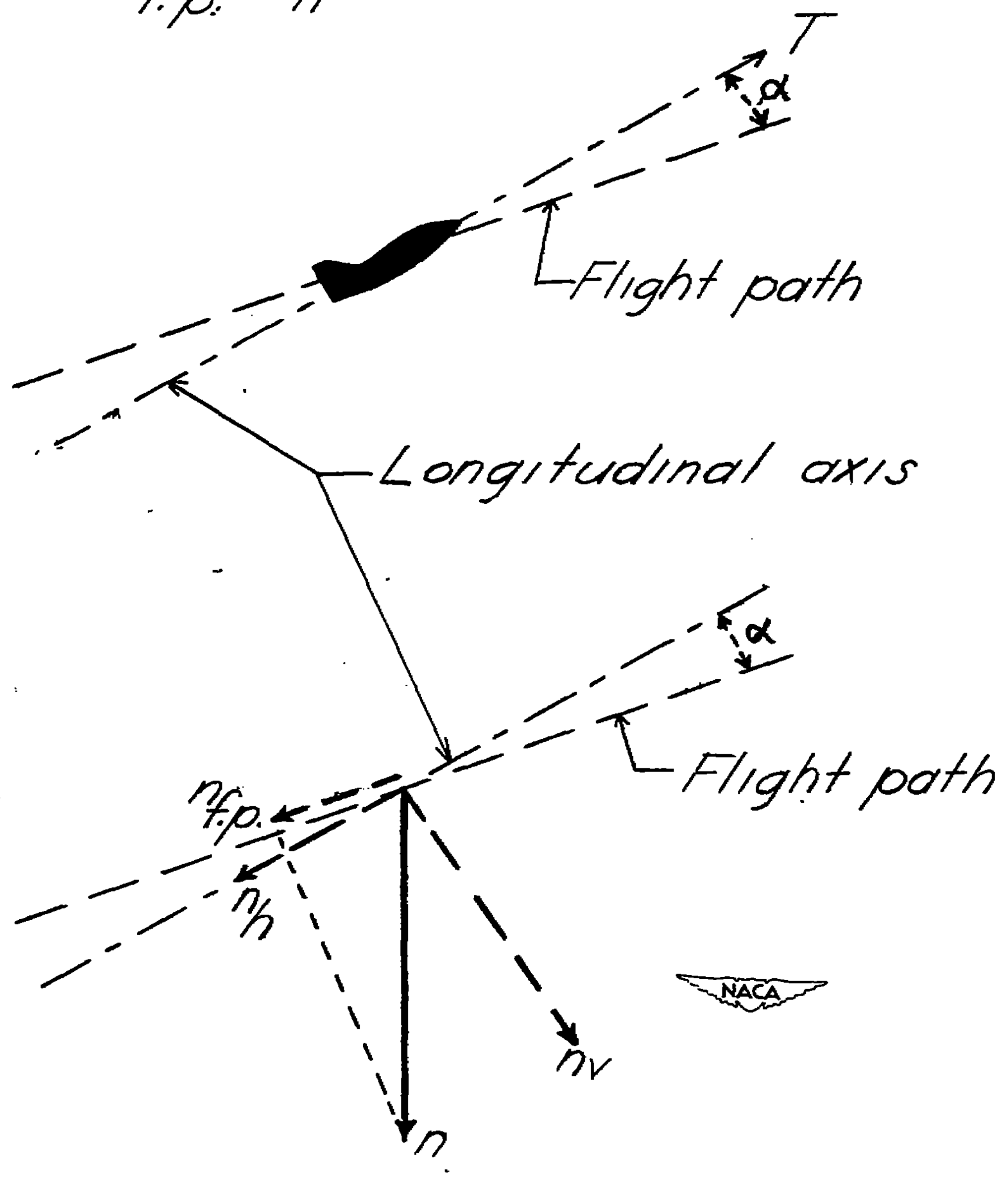

Figure 3.- Resolution of total airplane acceleration vector along longitudinal axes.

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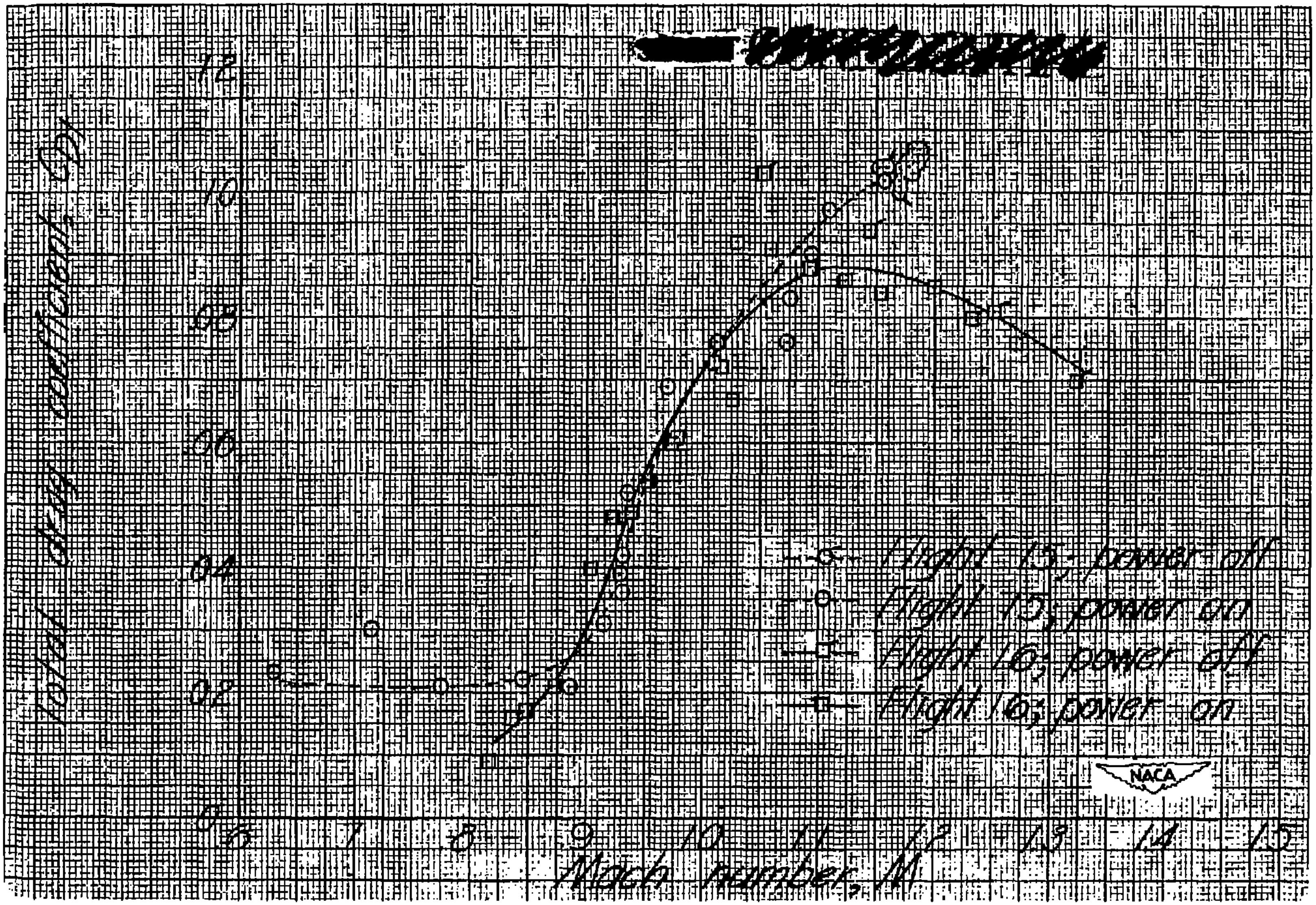

Figure 4.- Variation of total drag coefficient with airplane Mach number of X-1 airplane; 8 percent wing.

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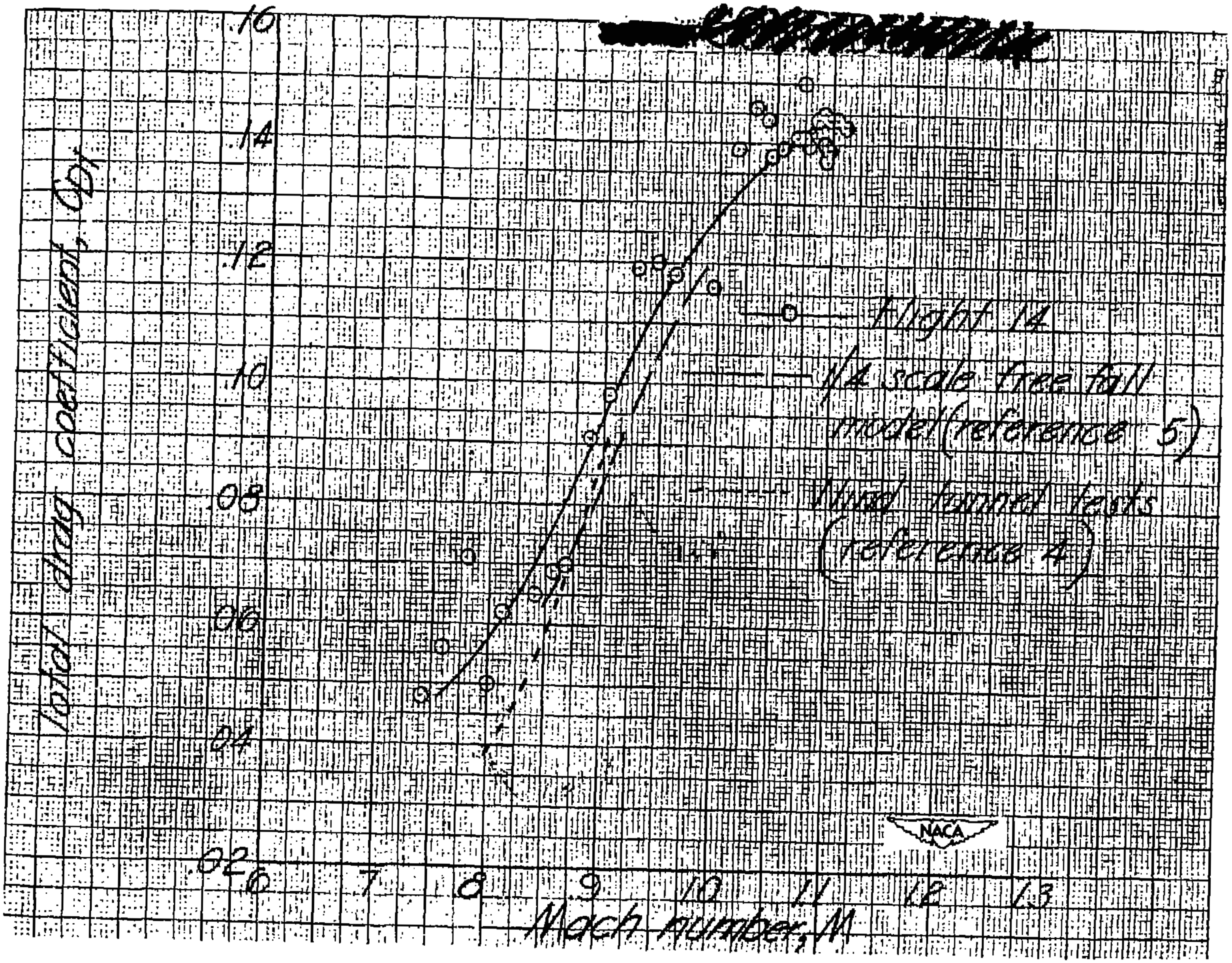

Figure 5.- Variation of total drag coefficient with airplane Mach number of X-1 airplane; 10 percent wing.

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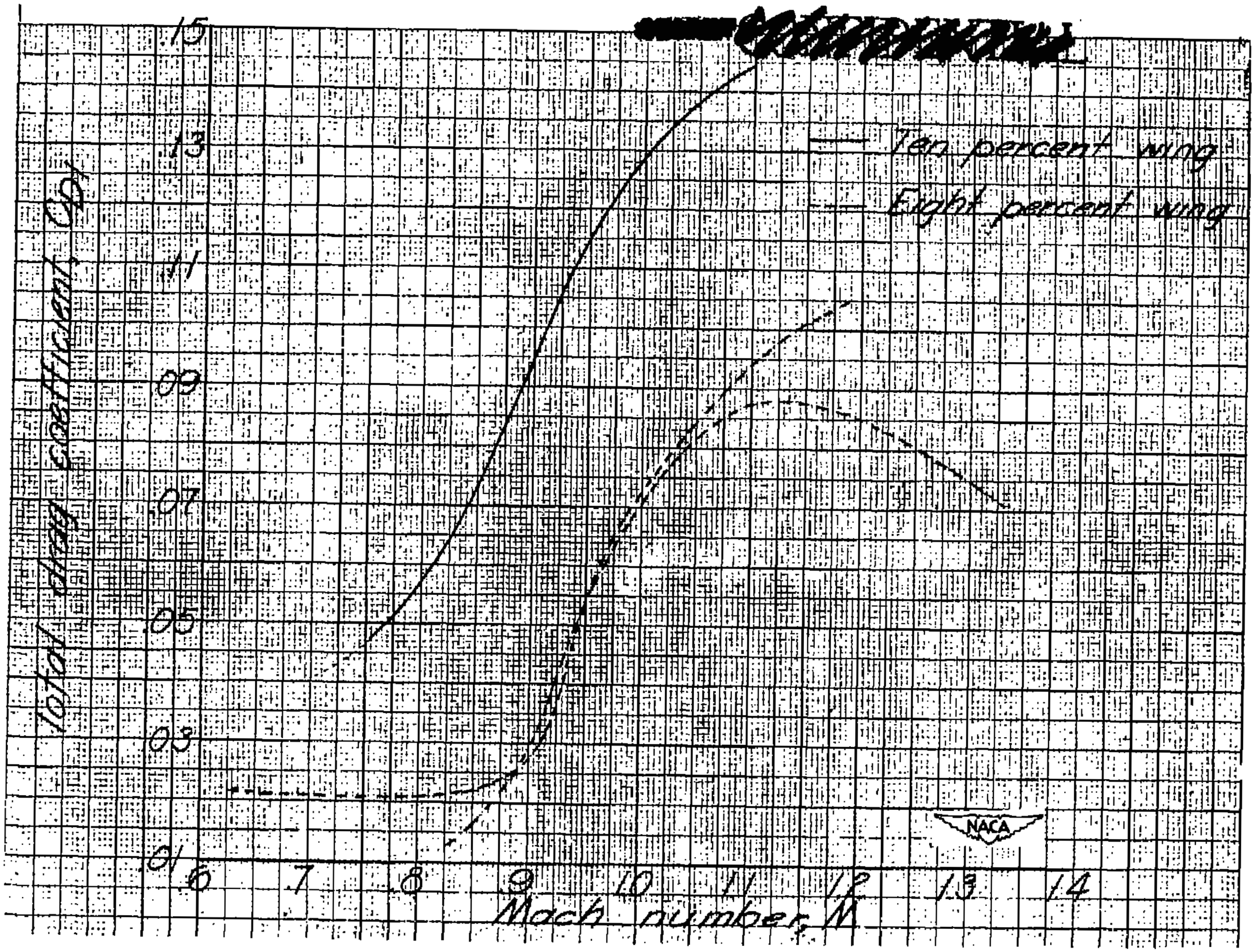

Figure 6.- Comparison of total drag coefficient with Mach number of X-1 airplanes.

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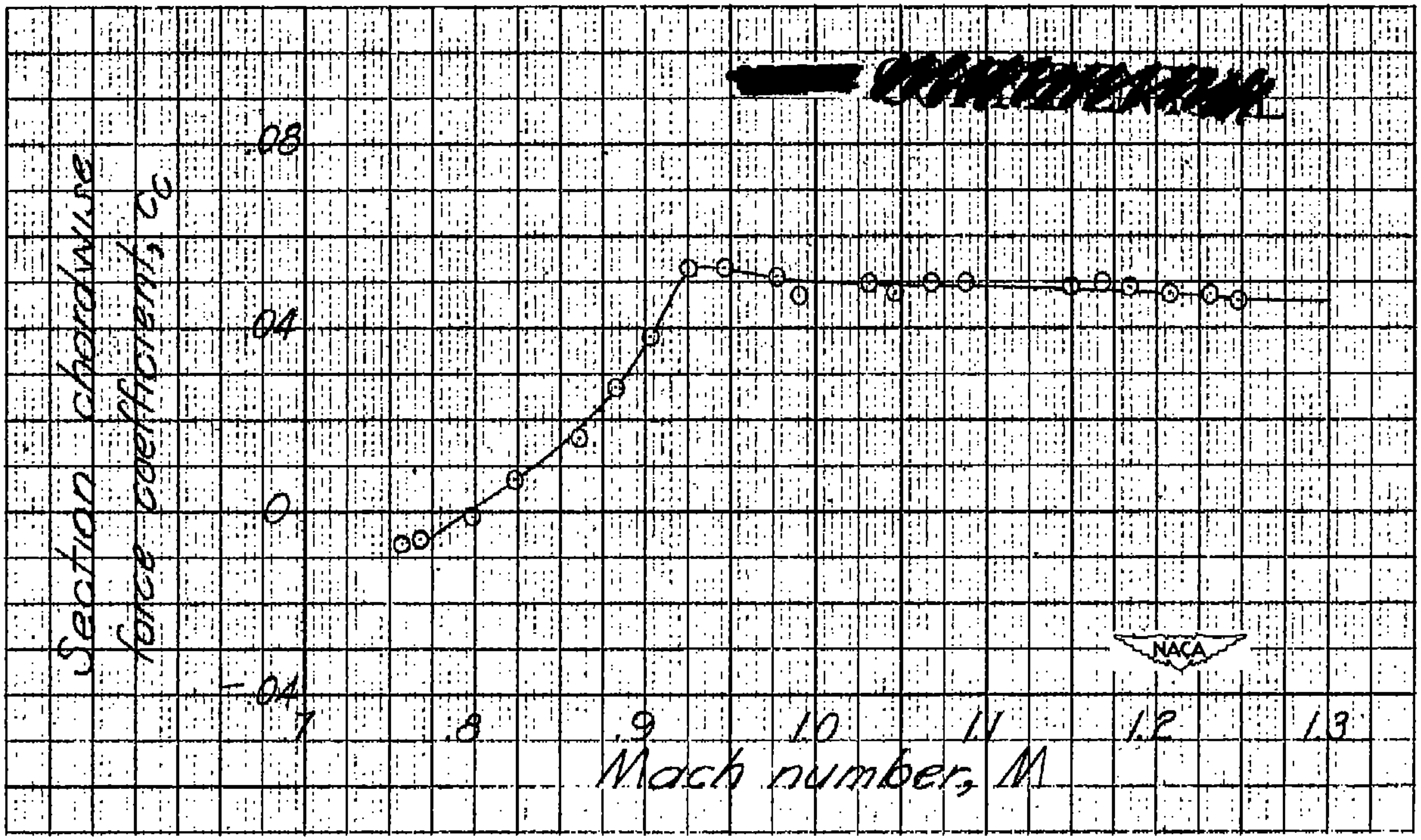

Figure 7.- Variation of chordwise force coefficient with airplane Mach number for wing pressure survey station at midsemispan on X-1 airplane; 8 percent wing.

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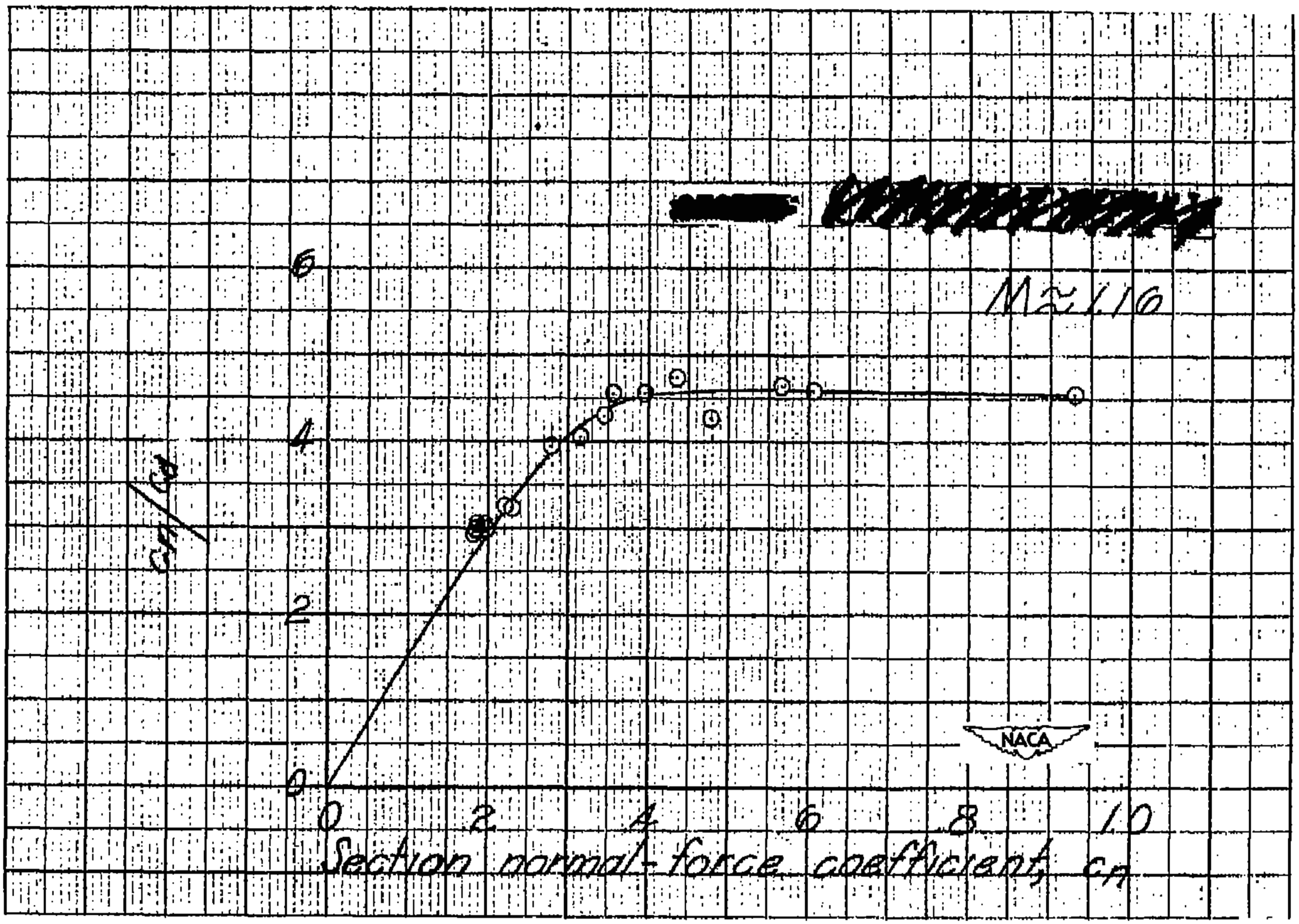

Figure 8.- Variation of section normal force-section drag ratio with section normal force of X-1 airplane; 8 percent wing.

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